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EDWIN DUNKIN, F.R.S., President, in the Chair.

Charles Michie Smith, B.Sc., F.R.S.E., Professor of Physical Science, Madras Christian College; and

Arthur Stanley Williams, Walsingham House, West Brighton;

were balloted for and duly elected Fellows of the Society.

The Observations of the Moon made at the Radcliffe Observatory during the Year 1883, and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables. By E. J. Stone, M.A., F.R.S.

The present paper contains the Right Ascensions and North Polar Distances of the Moon as deduced from the observations made at the Radcliffe Observatory during the year 1883. I have compared these results with those deduced from Hansen's Lunar Tables on two suppositions:

1. That the mean times, found in the usual way from the sidereal times at mean noon given in the *Nautical Almanac*, were not changed in 1864;

2. That the mean times were changed in 1864 in accordance with the views which I have explained in Papers already communicated to the Society.

The corrections which I have applied to the mean times are computed from the expression

$$+0^{s}\cdot55+24^{h}\times\frac{0\cdot060216}{1296027\cdot618184}\times\text{days from 1864 Jan. 1,}$$

and are added to the adopted sidereal times at each mean noon since 1864. Here $+0^{s}\cdot55$ is a constant, but the second term is a variable one, and soon becomes important. The necessity for such a correction, after the adopted value of the Sun's mean

motion in longitude was changed in the expression of the sidereal time in terms of the mean solar time from n to $n+\delta n$,

$$\frac{\delta n}{n} = \frac{0{\cdot}060216}{1296027{\cdot}618184},$$

follows from exactly the same reasoning as that which compels us to replace the sidereal time

$$= s = a + (24^{h} + n)t,$$

when t is expressed in days by

$$s = a + 24^{h}\left(1 + \frac{\delta n}{n}\right)t' + (n + \delta n)t',$$

or

$$s = a + 24^{h} \times 365{\cdot}25\,t' + 365{\cdot}25\,nt',$$

when we adopt instead of a day a Julian year of 365·25 such days as our unit. In this case

$$\frac{\delta n}{n} = 364{\cdot}25;$$

but if we were to omit the term

$$24^{h} . \frac{\delta n}{n} . t',$$

and to write

$$s = a + 24^{h}t' + 365{\cdot}25\,nt',$$

and then to assume that at the r^{th} *day* from epoch we could take $t' = r$, and thus find sidereal time at r^{th} *mean noon* $= 365{\cdot}25\,nr$, we should have made identically the same error in theory which we have made since 1864. The only difference is that when

$$\frac{\delta n}{n} = 364{\cdot}25$$

the errors which arise from such mistakes would be sufficiently large to prevent them being made in practice, and such errors have, therefore, never been made in practical astronomy; but when

$$\frac{\delta n}{n} = \frac{0{\cdot}060216}{1296027{\cdot}618184},$$

the errors accumulate so slowly that it is only after a lapse of some years that their effects become sufficiently sensible to be separated from personal errors and the defects of Lunar theory. But, if the omission of the term

$$24^{h} . \frac{\delta n}{n} . t'$$

is absurd when

$$\frac{\delta n}{n}$$

is large, it cannot be correct to omit this term when

$$\frac{\delta n}{n}$$

is small. As my theoretical views have been disputed, I have shown that this correction does, as a matter of fact, remove the discordances between Hansen's Lunar Tables and observations over the whole period of twenty years which have elapsed since the change in the units of time took place. The following are the facts bearing on this question :—

(1) Hansen's Lunar Tables represented the motions of the Moon with great accuracy for many years before 1863. The mean yearly error, 1847–1864, was always small, and generally about $-1''\cdot5$.

(2) In 1864 we changed the scale upon which our mean times are measured, or the ratio of the sidereal day to the tabular day. This is now admitted.

(3) I have given mathematical proofs which no one, at all events at present, has shown to be in error, that this change of units requires the correction

$$24^h \cdot \frac{\delta n}{n} \cdot t$$

to be applied to our present sidereal times at mean noon, in order to obtain the sidereal time at Bessel's old mean noon to which our tabular quantities refer. This correction is equivalent to a change of the adopted unit of time in the proportion of

$$1 : \left(1 + \frac{\delta n}{n}\right).$$

(4) When this correction is applied to our mean times, the discordances between Hansen's Lunar Tables and observations for the twenty years 1864–1883 are very little greater than they were before 1863.

The statements which have been made that the times are thus over-corrected do not appear to be warranted by the facts. The mean error in longitude was negative for years before 1864, and should, therefore, be negative now, if no change had been made and Hansen's Tables were perfect. The changes in the errors of Hansen's Tables are very small, as shown by the results. The mean of the four greatest negative errors in the comparison of Hansen's Tables in longitude with the Greenwich observations was $-9''\cdot08$ in 1862, and $-6''\cdot95$ in 1863; whilst the mean of the four greatest positive errors was respectively $+1''\cdot51$ in 1862, and $+3''\cdot52$ in 1863. The Radcliffe observations in 1882 and 1883 show corresponding mean errors of $-7''\cdot17$ and $-6''\cdot60$, and $+3''\cdot93$ and $+3''\cdot50$ respectively. There is therefore no over-correction. The error in time increases from $0^s\cdot55$ at the rate of about $1^s\cdot46$ per annum, but Hansen's Tables correctly represent the motion over the twenty years. This cannot be the result of an accident: the quantities dealt with are too large.

As my paper which gave the separate results of a comparison between Hansen's Lunar Tables and the Greenwich Observations 1864–1881, when the mean times were corrected in accordance with my theoretical views, has not been printed, I have appended to this paper the mean annual results.

TABLE I.

Radcliffe Observations of the Moon, 1883.

Corr. to be subtracted from M.T. computed directly from Sid. Time at Mean Noon from N.A.	Obs.	Day.	Observed R.A.	Secs. of Hansen's R.A.	Diff. (H.−Obs.)	Corr. due to Error in Time.	Residual Error in R.A.	Observed N.P.D.	Secs. of Hansen's N.P.D.	Diff. (H.−Obs.)	Corr. due to Error in Time.	Residual Error in N.P.D.
s			h m s	s	s	s	s	° ′ ″	″	″	″	″
28·36	R.	Jan. 15	1 15 48·32	49·12	+0·80	−1·08	−0·28	79 31 19·00	16·22	−2·78	+5·05	+2·27
28·36	W.	16	2 13 2·94	3·83	+0·89	−1·10	−0·21	75 28 61·52	58·71	−2·81	+4·12	+1·31
28·37	F.B.	18	4 10 51·69	52·48	+0·79	−1·13	−0·34	70 22 5·83	5·94	+0·11	+1·59	+1·70
28·39	W.	23	8 53 4·01	4·95	+0·94	−0·97	−0·03	77 39 22·50	25·93	+3·43	−4·16	−0·73
28·40	R.	26	11 17 5·30	6·28	+0·98	−0·88	+0·10	89 56 22·27	26·05	+3·78	−4·91	−1·13
28·47	W.	Feb. 13	2 53 51·74	52·51	+0·77	−1·13	−0·36	73 27 58·92	57·11	−1·81	+3·39	+1·58
28·48	F.B.	15	4 52 40·49	41·40	+0·91	−1·13	−0·22	69 55 56·51	59·03	+2·52	+0·62	+3·14
28·48	R.	16	5 51 7·12	7·75	+0·63	−1·10	−0·47	70 0 9·52	9·91	+0·39	−0·75	−0·36
28·50	R.	19	8 34 44·81	45·41	+0·60	−0·98	−0·38	76 26 13·53	17·15	+3·62	−3·84	−0·22
28·51	W.	22	10 59 52·46	53·55	+1·09	−0·89	+0·20	88 13 28·20	32·28	+4·08	−4·89	−0·81
28·51	R.	23	11 46 6·56	7·43	+0·87	−0·89	−0·02	92 26 37·33	41·09	+3·76	−4·83	−1·07
28·62	R.	Mar. 23	12 16 36·41	37·31	+0·90	−0·89	+0·01	95 6 35·24	39·98	+4·74	−4·66	+0·08
28·64	R.	26	14 39 49·06	49·93	+0·87	−0·96	−0·09	105 29 38·11	39·28	+1·17	−3·09	−1·92
28·72	R.	April 16	9 41 53·88	54·29	+0·41	−0·93	−0·52	81 36 49 84	53·87	+4·03	−4·48	−0·45
28·74	R.	20	12 47 44·17	44·91	+0·74	−0·91	−0·17	97 45 42·66	45·89	+3·23	−4·44	−1·21
28·74	F.B.	21	13 35 1·44	2·31	+0·87	−0·93	−0·06	101 23 47·01	50·22	+3·21	−3·99	−0·78
28·76	W.	25	16 59 48·20	49·43	+1·23	−1·05	+0·18	109 42 25·96	23·16	−2·80	−0·41	−3·21

Corr. to be subtracted from M.T. computed directly from Sid. Time at Mean Noon from N.A.	Obs.	Day.	Observed R.A.	Secs. of Hansen's R.A.	Diff. (H.−Obs.)	Corr. due to Error in Time.	Residual Error in R.A.	Observed N.P.D.	Secs. of Hansen's N.P.D.	Diff. (H.−Obs.)	Corr. due to Error in Time.	Residual Error in N.P.D.
s			h m s	s	s	s	s	o ′ ″	″	″	″	″
28·77	R.	April 29	20 40 28·25	29·31	+1·06	−1·07	−0·01	102 52 34·19	29·53	−4·66	+4·21	−0·45
28·84	R.	May 16	11 45 34·31	34·80	+0·49	−0·89	−0·40	92 25 4·68	7·87	+3·19	−4·79	−1·60
28·86	F.B.	22	16 42 15·19	16·35	+1·16	−1·05	+0·11	109 33 40·03	38·35	−1·68	−0·80	−2·48
28·87	R.	23	17 37 11·21	12·19	+0·98	−1·07	−0·09	109 44 11·88	8·67	−3·21	+0·40	−2·81
28·87	F.B.	24	18 32 45·93	46·92	+0·99	−1·08	−0·09	108 50 63·65	59·80	−3·85	+1·65	−2·20
28·95	W.	June 12	11 28 8·39	9·19	+0·80	−0·91	−0·11	90 44 11·16	16·02	+4·86	−4·88	−0·02
28·96	W.	14	13 1 0·04	1·01	+0·97	−0·92	+0·05	98 43 39·19	42·85	+3·66	−4·38	−0·72
29·09	W.	July 17	17 50 6·01	6·82	+0·81	−1·10	−0·29	109 36 27·27	26·01	−1·26	+0·61	−0·65
29·10	W.	19						106 19 9·74	5·84	−3·90	+3·19	−0·71
29·12	R.	26	2 18 46·18	47·32	+1·14	−1·14	0·00	76 6 60·21	54·30	−5·91	+4·17	−1·74
29·20	R.	Aug. 13	17 25 10·48	11·33	+0·85	−1·08	−0·23	109 33 1·72	1·06	−0·66	0·00	−0·66
29·20	W.	14	18 21 8·01	9·05	+1·04	−1·11	−0·07					
29·21	W.	16	20 15 29·52	30·64	+1·12	−1·12	0·00	104 38 34·36	30·52	−3·84	+3·78	−0·06
29·22	W.	18	22 9 57·41	58·83	+1·42	−1·12	+0·30	96 31 61·69	58·37	−3·32	+5·54	+2·22
29·23	W.	22	2 0 37·30	38·59	+1·29	−1·16	+0·13	77 30 41·25	37·62	−3·63	+4·56	+0·93
29·24	R.	23	3 0 24·64	25·63	+0·99	−1·18	−0·19	74 5 36·79	35·59	−1·20	+3·41	+2·21
29·32	F.B.	Sept. 13	20 44 25·51	26·54	+1·03	−1·12	−0·09	102 47 15·04	10·88	−4·16	+4·24	+0·08
29·33	W.	15	22 38 51·20	52·27	+1·07	−1·13	−0·06	94 4 60·31	55·44	−4·87	+5·81	+0·94
29·33	F.B.	16	23 36 54·29	55·65	+1·36	−1·15	+0·21	89 2 16·42	11·53	−4·89	+6·02	+1·13

Corr. to be subtracted from M.T. computed directly from Sid. Time at Mean Noon from N.A.	Obs.	Day.	Observed R.A.	Secs. of Hansen's R.A.	Diff. (H.−Obs.)	Corr. due to Error in Time.	Residual Error in R.A.	Observed N.P.D.	Secs. of Hansen's N.P.D.	Diff. (H.−Obs.)	Corr. due to Error in N.P.D.	Residual Error in N.P.D.
s			h m s	s	s	s	s	° ′ ″	″	″	″	″
29·34	F.B.	Sept. 17	0 35 55·09	56·64	+1·55	−1·17	+0·38	83 59 32·85	25·90	−6·95	+5·79	−1·16
29·44	R.	Oct. 12	22 9 14·29	15·15	+0·86	−1·11	−0·25	96 28 58·55	53·26	−5·29	+5·41	+0·12
29·44	W.	13	23 6 2·44	3·42	+0·98	−1·13	−0·15	91 41 18·16	14·39	−3·77	+5·89	+2·12
29·45	W.	16	2 6 30·62	31·92	+1·30	−1·24	+0·06	77 19 59·79	57·49	−2·30	+4·70	+2·40
29·46	F.B.	17	3 10 21·05	22·31	+1·26	−1·27	−0·01	73 52 45·45	43·07	−2·38	+3·38	+1·00
29·47	R.	21	7 20 23·45	24·59	+1·14	−1·13	+0·01	73 2 59·29	61·19	+1·90	−2·60	−0·70
29·55	R.	Nov. 9	22 39 12·09	12·89	+0·80	−1·09	−0·29	93 59 51·12	47·70	−3·42	+5·52	+2·10
29·55	F.B.	10	23 34 44·28	45·24	+0·96	−1·12	−0·16	89 12 8·58	5·17	−3·41	+5·81	+2·40
29·56	R.	12	1 32 14·97	15·81	+0·84	−1·21	−0·37	79 38 52·17	49·86	−2·31	+5·22	+2·91
29·58	R.	16	5 51 22·97	24·23	+1·26	−1·27	−0·01	70 54 47·79	47·27	−0·52	−0·64	−1·16
29·60	R.	22	11 18 56·86	57·89	+1·03	−0·94	+0·09	89 23 6·35	12·44	+6·09	−4·91	+1·18
29·65	W.	Dec. 5	21 27 18·78	19·71	+0·93	−1·05	−0·12	99 52 44·84	40·34	−4·50	+4·61	+0·11
29·68	F.B.	12	4 10 13·52	14·60	+1·08	−1·30	−0·22	71 46 9·08	8·69	−0·39	+2·03	+1·64
29·69	R.	14	6 21 8·05	9·14	+1·09	−1·27	−0·18	71 14 14·22	16·17	+1·95	−1·37	+0·58
29·69	F.B.	15	7 23 50·56	51·71	+1·15	−1·21	−0·06	73 1 6·26	8·70	+2·44	−2·80	−0·36
	Mean of errors without regard to sign ...				0·982		0·169			3·173		1·270
	Mean errors for year				+0·982		−0·095			−0·686		+0·096

Observers: W. = Mr. Wickham. R. = Mr. Robinson. F.B. = Mr. F. Bellamy.

TABLE II.

Radcliffe Observations of the Moon, 1883. *Errors of Longitude and Ecliptic N.P.D.*

Day 1883.	Errors of Longitude. Corrected for Error in Time.	Uncorrected.	Errors of Ecl. N.P.D. Corrected for Error in Time.	Uncorrected.
	″	″	″	″
Jan. 15	−4·69	+11·99	+0·55	+1·87
16	−3·31	+13·13	+0·23	+1·64
18	−5·04	+10·95	+0·79	+2·15
23	−0·63	+14·23	−0·58	−0·48
26	+0·94	+15·09	−1·63	−2·28
Feb. 13	−5·41	+11·13	+0·02	+1·46
15	−3·45	+12·45	+2·76	+4·00
16	−6·63	+ 8·84	−0·45	+0·51
19	−5·44	+ 9·41	+1·17	+1·33
22	+2·46	+16·69	−1·90	−2·54
23	−0·70	+13·52	−0·86	−1·74
Mar. 23	+0·17	+14·25	+0·01	−1·00
26	−1·83	+12·34	−1·43	−2·72
April 16	−7·46	+ 7·10	+2·12	+1·80
20	−2·80	+11·40	−0·13	−1·31
21	−1·11	+13·09	−0·41	−1·66
25	+2·20	+17·02	−3·45	−4·57
29	−0·03	+16·24	−0·47	−0·53
May 16	−6·16	+ 8·04	+0·92	+0·01
22	+1·21	+16·04	−2·67	−3·86
23	−1·38	+13·72	−2·86	−2·68
24	+1·40	+14·26	−2·27	−3·05
June 12	−1·53	+13·02	+0·63	−0·26
14	+0·41	+14·70	−0·95	−2·15
July 17	−4·12	+11·46	−0·58	−1·46
26	−0·57	+17·61	−1·64	−0·15
Aug. 13	−3·29	+11·98	−0·47	−1·37
16	+0·01	+16·79	−0·06	−0·10
18	+3·40	+21·03	+3·66	+4·39
22	+1·46	+18·99	+1·53	+3·11
23	−3·25	+14·04	+1·35	+2·87
Sept. 13	−1·30	+15·70	−0·27	−0·06
15	+0·48	+16·73	+0·54	+1·48

Day 1883.	Errors of Longitude. Corrected for Error in Time.	Uncorrected.	Errors of Ecl. N P.D. Corrected for Error in Time.	Uncorrected.
	"	"	"	"
Sept. 16	+2·45	+20·74	+2·29	+3·57
17	+5·67	+24·00	+1·16	+2·71
Oct. 12	−3·54	+13·91	−1·21	−0·41
13	−2·90	+15·05	+1·08	+2·22
16	+0·01	+18·68	+2·56	+4·30
17	−0·41	+18·15	+0·92	+2·60
21	+0·05	+16·52	−0·71	−0·35
Nov. 9	−4·83	+12·42	+0·32	+1·32
10	−3·17	+14·62	+1·26	+2·55
12	−6·15	+12·38	+0·71	+2·39
16	−0·13	+17·92	−1·16	−0·27
22	+1·71	+16·68	+0·56	−0·45
Dec. 5	−1·72	+14·51	−0·45	+0·05
12	−3·39	+15·25	+1·04	+2·45
14	−2·54	+15·58	+0·68	+1·36
15	−0·91	+16·74	−0·23	+0·05
Mean of errors without regard to sign	2·528	14·615	1·137	1·789
Mean errors for year ...	−1·547	+14·615	+0·041	+0·342

Table III.

Observations of the Moon, 1862 to 1883. *Uncorrected and Corrected for Error in Time.*

Hansen − Observed.

Year.	R.A. Uncorrected.	R.A. Corrected.	N.P.D. N.P.D. Increasing Uncorrected.	N.P.D. Increasing Corrected.	N.P.D. Decreasing Uncorrected.	N.P.D. Decreasing Corrected.
	s	s	"	"	"	"
1862 Gr.	−0·191	−0·191	+0·00	+0·00	+0·02	+0·02
1863 „	−0·129	−0·129	+0·04	+0·04	−0·27	−0·27
1864 „	+0·001	−0·048	−0·18	−0·32	−0·53	−0·34
1865 „	+0·085	−0·019	−0·33	−0·60	−0·89	−0·53
1866 „	+0·135	−0·020	+0·62	+0·16	−0·53	0·00
1867 „	+0·235	+0·028	+0·80	+0·26	−0·35	+0·36
1868 „	+0·275	+0·015	+1·26	+0·36	−0·74	+0·07
1869 „	+0·295	−0·016	+0·94	−0·15	−1·05	+0·06
1870 „	+0·329	−0·044	+0·92	−0·40	−1·44	−0·12

Year.	R.A. Uncorrected.	R.A. Corrected.	N.P.D. N.P.D. Increasing Uncorrected.	N.P.D. N.P.D. Increasing Corrected.	N.P.D. N.P.D. Decreasing Uncorrected.	N.P.D. N.P.D. Decreasing Corrected.
1871 Gr.	+0·448	+0·019	+1·93	+0·15	−2·49	−0·70
1872 „	+0·478	−0·002	+2·16	+0·07	−2·93	−0·64
1873 „	+0·522	−0·008	+3·09	+0·75	−3·11	−0·46
1874 „	+0·597	+0·026	+3·28	+0·64	−3·53	−0·44
1875 „	+0·649	+0·026	+3·03	+0·03	−3·40	−0·15
1876 „	+0·637	−0·040	+4·11	+0·57	−3·05	+0·73
1877 „	+0·585	−0·146	+4·76	+0·68	−2·95	+0·54
1878 „	+0·530	−0·251	+4·47	+0·22	−2·29	+1·32
1879 „	+0·613	−0·241	+4·25	+0·41	−3·32	+0·48
1880 „	+0·663	−0·232	+3·66	−0·27	−3·44	+0·34
1881 „	+0·687	−0·266	+3·30	−0·40	−3·98	0·00
1882 „	+0·82					
1882 Rad.	+0·858	−0·162	+2·73	−0·83	−3·44	+0·70
1883 „	+0·982	−0·095	+2·60	−0·81	−3·06	+0·75

On the Proper Motions of Forty Stars in the Pleiades, both Absolute and Relative. By Prof. C. Pritchard, D.D., F.R.S.

(*Abstract.*)

The Memoir which I am about to present to the consideration of the Society, consists mainly of two separate and entirely independent investigations of the proper motions of forty stars in the *Pleiades*. It originated primarily in a desire to test the capacity of a new Differential Micrometer which I had devised, under the expectation that it would enable me to measure with great accuracy celestial arcs to the extent of some twenty minutes; a distance which seemed to me considerably greater than could be reached with security by means of any filar micrometer with which I was acquainted. I purposed to apply this new form of micrometer, if successful, to a systematic investigation of stellar parallax, which I then intended to make an especial object of research, in the observatory under my direction at Oxford. I applied the instrument in the first instance to the *Pleiades*, in consequence of a remark* made by Bessel, to the effect that his own measures of the relative coordinates of certain members of this historic group had been effected with so much accuracy by means of his heliometer, that advantage might henceforth be taken of his scrupulous labours therein, to test the accuracy of other instruments, and, at the same time, assist in determining their scales.

I had proceeded to a considerable extent in this investigation

* Beobachtungen verschiedener Sterne der Plejaden, 'Astronomische Untersuchungen,' erster Band. S. 209.

when, becoming satisfied with the capacity of the new micrometer, I resolved to still further utilise the observations by widening the scope of the work, and by embarking on a systematic measurement of the relative positions of the more prominent members of the group, with the view of ascertaining their relative proper motions since the time of Bessel's heliometer measures made some forty years ago.

The instrument in question affords the means of measuring arcs with equal facility in the three coordinate directions of Right Ascension, Declination, and Distance. Consequently, if all three were measured, there would arise at once the means of testing the accuracy of the observations. This seemed to me to be a great gain, and I have uniformly applied this test to the observations recorded in the present Memoir.

Such, then, are the circumstances under which the research commenced. As I proceeded with it, and endeavoured to make it complete, the questions before me widened out, and new objects of research presented themselves in close connection with the original inquiry. It became desirable for instance to record the relative magnitudes, or degrees of lustre, presented by the members of the group subjected to the micrometer. Estimations made by the eye on these objects as viewed in the field of the telescope, seemed to me to be eminently unsatisfactory. In support of this remark, I may mention that out of estimations made by eminent observers, such as Flamsteed, Bradley, Mayer, Piazzi, Bessel, Argelander, and Wolf, no two agree in the order of the relative brightness of the eight principal stars in the cluster.* These considerations led me to the invention of the photometric method of measurement of relative brightness by means of the '*Wedge Photometer*,' and this has already appeared in the Memoir on the subject, printed in the last volume of the Society's Transactions, and which I trust, before long, to complete as a new Uranometria of all the stars visible to the naked eye from the Pole to the Equator.

In the course of the reduction of the micrometer measures another question also not unnaturally arose. The results thus obtained are from *differential* observations. But scattered about in the records of many observatories, from the time of Bradley downwards to the present time, there are numerous observations of several members of the group, made with meridian instruments, and affording reliable measures of their absolute Right Ascensions and Declinations. If therefore these valuable observations, made at different epochs and by various observers of great eminence, were reduced on a uniform and systematic plan, it would thereby be possible to deduce the present coordinates and the proper motions of the objects to which these observations refer. The work, I felt, would be somewhat laborious; but it would supply the means of an interesting and

* Description du groupe des Pléiades, par M. C. Wolf, p. A 24.

somewhat novel intercomparison between the results obtained by a long series of meridian observations, and those accruing from differential measures, made away from the meridian. Accordingly I was led to undertake the task, the numerical results of which are now complete and ready for presentation to the Society.

There are fourteen stars in the *Pleiades* whose places have been sufficiently obtained by meridian observations. They extend for the most part through a period of one hundred and thirty years, and are worthy of various and perhaps of determinable degrees of reliance. In systematically effecting their reduction, I have followed and somewhat extended the plan pursued by Argelander in the seventh volume of the Bonn observations, largely availing myself of the facilities afforded by the later labours of Professors Newcomb and Boss. The result of this section of the present research, consists in the determination of the most probable absolute coordinates and proper motions of the fourteen stars in question. These proper motions thus obtained from the best existing meridian observations, are then compared with those resulting from micrometrical measurements. For the latter purpose recourse is had to the heliometer measures made at Königsberg between 1838–41; to a very valuable set of differential measures made at Paris by Dr. Wolf in 1874; and to the measures made at Oxford with the 'Duplex Micrometer' between 1878–1880.*

These three sets of observations are combined together by means of equations of condition; and, as in the case of the forementioned meridian work, furnish at once the most probable relative coordinates of the forty stars in question, together with their relative proper motions.

The final results of these investigations are as follows:— First, with regard to the fourteen stars which have been measured by the two thoroughly independent processes; the general accord of the final results points unmistakably to the existence of certain small motions of these stars *inter se*; but of so slight an amount, that their exact determination does not seem fully within the reach of observations as yet extant; these must be left for the effects of a greater lapse of time, which shall make them more directly apparent in amount, and to the astronomy of the future. Of the remaining stars, although meridian observations do not at present exist so as to corroborate the evidences of relative motion afforded by the combined micrometer measures made at Königsberg, Paris, and Oxford, nevertheless the fact of these minute displacements is, I think, now established beyond

* In addition to these, there is another apparently valuable set of measures made at Washington about the year 1860. These observations, however, do not appear to have been systematically reduced. In the Washington Catalogue for 1860, the absolute coordinates are given, but the information there supplied is, I regret, not sufficient to enable me to combine them with the other series of coordinates here mentioned.

doubt. An independent confirmation of these results is also obtained from a comparison of '*distance*' measured at Königsberg and at Oxford.

Another remark also occurs, which is this: the relative displacements of these distant suns, although not distinctly and accurately measurable in numerical extent, appear to vary both in direction and amount; indicating thereby the mutual influence of a group of gravitating bodies, and not simply that common motion of the whole which would necessarily arise simply from the translation of the solar system in space.

In further connection with the completion, for the present, of this very interesting inquiry into the observable motions of a cosmical system, I may take this opportunity of stating, that I have laid the foundation for a similar enquiry, destined for the astronomers of the future, by making with scrupulous care, in the University Observatory, a series of observations of the relative positions of some 250 stars of a cluster in *Cygnus* (39 Messier), which I hope, in due time, to communicate to the Society. Perhaps these measures, after the lapse of a century or more, may, like Bradley's observations, made 130 years ago, again serve to trace the effects of gravitation, in systems of suns, possibly detached from our own.

Oxford: 1884 *May* 8.

Observations made at the U.S. Naval Observatory, Washington.

By Prof. Asaph Hall.

(*Communicated by Commodore S. R. Franklin, U.S.N., Supt.*)

CONJUNCTION OF THE SATELLITES OF SATURN.

Mimas.

Date.		Wash. M.T. h m	Position.	Wt.	Remarks.
1883 Dec.	3	10 55·8	S.p.	3	
	3	12 10·8	S.p.	3	
	6	9 19·9	S.	3	
1884 Jan.	26	6 40·8	S.	3	
Feb.	1	9 46·5	N.	3	

Enceladus.

1883 Dec.	6	9 44·4	N.	3	
	17	8 42·3	N.	3	
	28	7 45·9	N.	2	
1884 Jan.	21	7 6·7	S.	3	
Feb.	1	6 18·0	S.	3	
	18	9 25·6	N.	3	
	29	8 35·1	N.	3	

Tethys.

Date.	Wash. M.T.	Position.	Wt.	Remarks.
	h m			
1883 Dec. 15	10 40·2	S.	2	Cloudy
17	7 59·3	S.	3	
1884 Jan. 2	8 50·5	N.	2	
3	7 36·5	S.	2	Very faint, hazy
4	6 8·1	N.	3	
20	7 15·6	S.	3	
21	5 54·7	N.	3	
Feb. 21	9 35·8	S.	2	

Dione.

1883 Nov. 4	11 12·7	N.	3	
Dec. 11	9 18·1	S.	1	Strong moonlight
1884 Jan. 6	9 0·8	N.	3	
17	7 44·7	N.	3	
Feb. 1	9 3·0	S.	3	
23	6 35·8	S.	2	Cloudy

Rhea.

1883 Dec. 17	10 0·3	N.	3	
1884 Jan. 20	6 38·1	S.	3	

Observations of the Satellites of Mars.

Phobos.

Date.	Wash. M.T.	p.	Wt.	Wash. M.T.	s.	Wt.	Remarks.
	h m	°		h m	″		
1884 Jan. 26	9 59·8	95·1	3	10 12·3	20·35	3	Very faint
Feb. 1	11 12·0	90·1	2	11 20·5	19·70	2	Very faint

Deimos.

1884 Jan. 22	11 32·7	89·8	2	...	...	...	Clouds
25	13 17·3	263·25	3	13 23·3	46·43	3	
25	14 39·3	268·45	2	14 45·8	49·23	2	
26	8 33·3	97·89	3	8 39·3	41·52	3	Faint
29	9 35·9	268·65	3	9 41·9	48·80	3	
29	10 54·4	272·03	3	11 0·9	47·25	3	Faint
Feb. 1	11 33·0	82·21	2	11 40·0	45·08	2	Faint
15	9 8·0	80·44	3	9 18·0	45·35	3	Faint
15	10 19·5	84·78	3	10 30·5	45·75	3	
20	10 58·7	82·51	2	11 9·2	44·73	2	Very faint

Comparison with Marth's Ephemeris.

Phobos.

	(C−O) Δp	Δs
	°	″
Jan. 26	−4·4	−1·44
Feb. 1	−3·0	−0·36

Deimos.

Jan. 22	+1·68	...
25	+1·21	−0·86
25	+0·58	−1·13
26	+0·33	+0·89
29	+0·02	−0·46
29	+0·70	−0·29
Feb. 1	+0·34	+0·42
15	+1·63	+0·01
15	+0·53	+0·56
20	+0·77	+0·19

Observations of the Companion of Sirius.

Date.	Sid. Time.	p.	s.	Wt.	Remarks.
	h	°	″		
1884·170	5·6	39·0	8·89	2	Very faint
·206	6·1	38·0	8·76	2	Faint
·209	6·2	37·5	8·64	2	Faint
·225	6·8	36·5	8·76	2	Very faint
·231	6·7	37·5	8·87	3	
·247	7·3	37·8	8·95	2	Faint
·250	7·4	37·2	8·87	2	
·269	7·9	37·8	8·74	3	

Mean Results.

	p.	s.
	°	″
1884·226	37·67	8·810

In observing the conjunctions of the satellites of *Saturn* the wire of the micrometer was set perpendicular to the major axis of the ring by means of the angle given in the American *Ephemeris*, p. 465, and the time was noted when the satellite was bisected

by the wire. The satellite was watched several minutes before and after the conjunction. On Dec. 3 *Mimas* was observed in conjunction with the preceding end of the Cassini division of the ring, and again when in conjunction with the preceding edge of the ball. On good nights, with the present opening of the ring, this satellite can be followed to conjunction with ease and certainty.

The two observations of the inner satellite of *Mars* were made with difficulty, and these observations are of little value except to show that the elements of this satellite are nearly correct. The outer satellite could be observed accurately for about one month when near opposition. It could be followed longer with our 26-inch glass, but it is hardly worth while to do this, and thus bring in a quantity of uncertain observations. In both cases the residuals in the angles indicate small corrections to the periods of these satellites, but these periods are no doubt accurate enough to carry forward the Ephemerides for several succeeding oppositions of the planet. As the motion of these satellites in angle of position is now direct, or different from what it was at the time of discovery, it seems better to wait for further observations—at least during one favourable opposition—before making a final discussion of the observations. The observations above are corrected for differential refraction, and for the figure of the planet.

I am much indebted to Mr. Marth for the Ephemerides of satellites that he publishes.

The companion of *Sirius* has been very faint and difficult to observe during the present year. This was owing chiefly, I think, to the very unfavourable weather that has prevailed. The rainfall at Washington has been about 21 inches during the first three months of the year.

The Motion of Hyperion. By Prof. Asaph Hall.

In the *Astronomische Nachrichten*, Nos. 2246 and 2263, I have called attention to the motion of this satellite of *Saturn*, and to the difficulties that prevent an accurate determination of this motion. These difficulties arise in part from the fewness of the observations made from the time of its discovery in 1848 until 1875. In fact, during this interval of twenty-seven years the only complete series of observations is that made by Mr. Lassell at the opposition of 1852. For this reason the mean motion of this satellite is not yet well known, and it appears that we must wait for still further observations; but the following results may be of some interest, and may induce some astronomer who has the means, to assist in observing this faint object.

Denoting by s the observed distance of the satellite from the

centre of *Saturn*, and by p the corresponding angle of position, the formulæ of Marth give

$$r \sin (H+u) = \frac{\rho}{\rho_0} s . \frac{\cos (p-k)}{\cos h}$$

$$r \cos (H+u) = \frac{\rho}{\rho_0} s . \sin (p-k)$$

In these formulæ r is the radius vector of the satellite, and u is the argument of the latitude, ρ is the distance of the planet from the Earth, and ρ_0 its mean distance from the Sun. The quantities h, k, and $\cos h$ depend on the position of the orbit plane of the satellite, and the Right Ascension and Declination of the planet; and hence these quantities may be tabulated when the inclination and node of the orbit plane with respect to the equator are given. The plane of the orbit of *Hyperion* coincides nearly with that of *Titan*, and its position might be assumed the same, but I have used my former determination of the node and inclination which does not differ much from those of *Titan*. The quantities h, k, and $\cos h$ were then tabulated for each of the oppositions 1875 to 1883, and the values of r and u were computed from the observed values of s and p. Then having the radii vectores and the angles u, which vary nearly as the true anomalies, the elements of the satellite in the plane of its orbit were found. The following table gives the results of this calculation. The first column gives the year of the opposition, and I have included Mr. Lassell's observations of 1852. The second column gives the number of equations of condition. Each observation furnishes an equation of the form

$$x + by + cz + n = 0,$$

where

$$b = r \cos u,\ c = r \sin u,\ n = p_0 - r,$$
$$x = \Delta p_0,\ y = -e \cos (N-P),\ z = e \sin (N-P);$$

and p_0 is an assumed value of the semi-parameter, N and P are the longitudes of the node and peri-saturnium on the equator, and e is the eccentricity of the orbit. These equations solved by the method of least squares gave the quantities in the following columns. The third and fourth columns give the resulting values of the semi-major axis, and the eccentricity of the orbit. The fifth column gives the value of the longitude of the peri-saturnium with respect to the equator. In the last column is given the average value of $\cos h$. It will be seen by the formulæ that $\cos h$ enters into the value of $r \sin (H+u)$, and when this cosine is very small the values of r and u may be largely affected by small errors of observation. For this reason I have omitted the years 1877 and 1878, when the value of $\cos h$ was less than one-tenth.

Date.	No. of Equations.	a	e	P	cos h.
1852·9	30	217″·05	0·1201	240°·182	0·33
1875·7	32	216·25	0·1026	174·242	0·23
1876·7	11	216·52	0·1290	156·922	0·15
1879·8	27	211·17	0·0780	93·173	0·13
1880·9	48	212·41	0·0823	60·012	0·23
1881·9	42	213·05	0·0898	36·908	0·30
1882·9	15	215·46	0·0884	20·043	0·37
1883·9	30	212·90	0·0982	353·272	0·41

This table shows a very large change in the value of P. These values may be represented very nearly by the formula

$$P = 174°{\cdot}242 - 20°{\cdot}344t - 0°{\cdot}10254t^2$$

t denoting the number of Julian years from the epoch 1875–7.

There is yet some uncertainty in the mean motion of *Hyperion*, but the best value is found probably by comparing Mr. Lassell's observations of 1852 with the recent ones. A comparison of these observations with my own of 1880 and 1882 gives the following value of the periodic time:

Sidereal Period = 21·276742 days;

and the synodical period is 21·318901 days.

On account of its mean distance and the eccentricity of its orbit *Hyperion* can approach very near to *Titan*; and since three times the period of one is nearly equal to four times the period of the other, there is probably a large perturbation of the motion of *Hyperion* by *Titan*, depending on the first powers of the eccentricities of their orbits. With the above value of the mean motion of *Hyperion* this perturbation will have a period of 19·185 years. The complete calculation of such a perturbation would be laborious in this case, since in computing the $b_s^{(i)}$ coefficients of Laplace we shall have

$$\alpha = \frac{176{\cdot}552}{213{\cdot}\ 98} = 0{\cdot}8250863,$$

and the series for these coefficients converge slowly.

Also a small change in the mean motion of *Hyperion* would have a large influence on the values of the coefficients in the expressions for the perturbations, and for this reason it does not seem worth while to give much time to such a work at present. But, in order to form some idea of the action of *Titan*, I have computed the coefficients in the perturbations of the radius vector and the true longitude, including the first powers of the eccentricities by the formulæ of the *Mécanique Céleste*, tome i. pp. 279, 280. In computing the values of $b_{\frac{1}{2}}^{(i)}$ and the derivatives, no attempt was made to carry the numerical approximations very far. Distinguishing the elements of *Titan* with an accent we have

$$a = 213''.98 \qquad a' = 176''.552$$
$$e = 0.1 \qquad e' = 0.029223$$
$$\tau = 21.276742 \text{ days} \qquad \tau' = 15.94545154 \text{ days}$$
$$m' = \text{mass of Titan.}$$

$$\delta r = am' \left\{ \begin{array}{l} -\ 0.32865 - 4.664 \cdot \cos(n't - nt + \epsilon' - \epsilon) \\ \qquad - 2.902 \cdot \cos 2(n't - nt + \epsilon' - \epsilon) \\ \qquad + 183.075 \cdot \cos 3(n't - nt + \epsilon' - \epsilon) \\ \qquad + 0.114 \cdot \cos 4(n't - nt + \epsilon' - \epsilon) \\ +\ 0.407 \cdot \cos(nt + \epsilon - \pi) - 0.1607 \cdot \cos(nt + \epsilon - \pi') \\ +\ 6.332 \cdot t \sin(nt + \epsilon - \pi) - 2.0570 \cdot t \sin(nt + \epsilon - \pi') \\ -166.367 \cdot \cos[(4n - 3n') \cdot t + 4\epsilon - 3\epsilon - \pi] \\ +\ 16.814 \cdot \cos[(4n - 3n') \cdot t + 4\epsilon - 3\epsilon' - \pi'] \end{array} \right\}$$

$$\delta v = m' \cdot \left\{ \begin{array}{l} +\ 30.065 \cdot \sin(n't - nt + \epsilon' - \epsilon) \\ \qquad + 5.739 \cdot \sin 2(n't - nt + \epsilon' - \epsilon) \\ \qquad - 366.667 \cdot \sin 3(n't - nt + \epsilon' - \epsilon) \\ \qquad - 0.932 \cdot \sin 4(n't - nt + \epsilon' - \epsilon) \\ -12.665 \cdot t \cos(nt + \epsilon - \pi) + 4.114 \cdot t \cos(nt + \epsilon - \pi') \\ -73156.67 \sin[(4n - 3n')t + 4\epsilon - 3\epsilon' - \pi] \\ +8307.50 \sin[(4n - 3n')t + 4\epsilon - 3\epsilon' - \pi'] \end{array} \right\}$$

The large coefficients in the perturbation of the longitude indicate that a small mass of *Titan* may have a great influence on the motion of *Hyperion*. But the mean motion of this last satellite must be known more exactly before any inference can be drawn. It is possible that the quantity $4n - 3n'$ may prove to be extremely small, so that we may have here a relation similar to that which exists among the satellites of *Jupiter*. Should such be the case the above values of δr and δv would be of little use, and the theory would be greatly changed. The mass of *Titan* is known only from estimates of its diameter, and by assuming its density. On several occasions during the past eight years, when the images were good, I have estimated the apparent diameter of *Titan* to be $0''.75$; but looking at some of the fixed stars on the same nights these also appeared to have small disks, and hence I am distrustful of diameters estimated in this way. According to Professor Pickering's photometric measurements, and assuming the densities of these satellites to be the same, we have

Mass of Titan = 387 times mass of Hyperion.

It is possible now, I think, to make a tolerably accurate ephemeris of *Hyperion* for the next opposition, but the one given in the American *Ephemeris* will serve very well for observing the satellite. It should be stated, however, that during the

opposition of 1883, *Hyperion* came to conjunction about one day sooner than the times given in that *Ephemeris*.

The observations of *Hyperion* made by Mr. Lassell during the opposition of 1852 are important, since they form the earliest complete series that we have. These observations are published in the *Monthly Notices*, vol. xiii. p. 181. I hope that Mr. Marth or some one familiar with Mr. Lassell's method of work, may be willing to revise the reductions and publish the observations with more detail.

1884 *April* 10.

Observations of the Companion of Sirius, made at the Dearborn Observatory, Chicago, U.S.A. By Prof. G. W. Hough and S. W. Burnham.

Date.	*p.*	*s.*
	°	″
1884·025	37·9	8·60
·057	36·7	8·35
·170	37·0	8·64
·186	37·1	8·39
·197	36·5	8·78
·200	36·5	8·58
·203	36·9	8·37
·217	37·0	8·51
·225	36·1	8·51
·233	35·9	8·30
·252	35·9	8·58
Mean = 1884·179	36·7	8·51

(*Observations by S. W. Burnham.*)

Date.	*p.*	*s.*
	°	″
1884·057	37·2	8·60
·167	39·3	8·33
·184	33·2	8·56
·195	36·4	8·11
·197	35·3	8·50
·200	35·8	8·31
·214	37·0	8·34
·217	36·3	8·22
·230	37·9	8·44
·233	35·5	8·51
Mean = 1884·19	36·4	8·39

Note on a Method of Reducing the Friction of the Polar Axis of a Large Telescope. By A. A. Common.

In large telescopes the friction of the polar axis is generally reduced by means of wheels placed so as to take from off the upper and lower bearings the greater part of the total weight. The points or lines of contact between those wheels and the axis are very small, and the least inequality in shape or in the hardness of the metal must produce for slow motions an extremely irregular action.

The plan of floating off some of this weight, and so reducing the friction, has been employed by me in the construction of an 18-inch and a 3-foot Reflector, but in both cases only in a partial manner.

In the account I gave (in vol. xlvi. of the *Memoirs* of this Society) of the mounting of this latter telescope, I mentioned that this principle could be applied in a very complete manner by so arranging matters that the centre of gravity of the moving parts should be over the centre of flotation.

I had then considered several ways of doing this. Two of these I now propose to mention more particularly, and I have little hesitation in doing so, as the working of the 3-foot telescope has been so good in this respect as to make me think that the complete application of this principle would be the best way we could have of ensuring the proper and equable motion of the telescope in time. The first plan, arranged for the 3-foot, mounted on what is known as the German form of mounting, is simple. It is to enlarge the diameter of the polar axis at the upper part by a drum or cylinder of cast iron, of such a diameter and depth as to get the requisite displacement of mercury contained in an outer cylinder surrounding the drum spoken of. Altering the figures to suit an object-glass of, say, 40 inches aperture and of about 60 feet focal length (as the largest that may be at present thought of), we should have as the weight brought down to the centre of the declination axis something like six tons. This could be dealt with effectively by making the drum on the polar axis about 6 feet diameter and 3 feet deep, something less than one-half of this being immersed. These figures are, of course, merely approximate, but if the size and weight of the object-glass be known, the rest can all be easily calculated.

Here, from the low position of the centre of gravity of the whole and its proximity to the upper bearing of the polar axis, it is possible to get the centre of gravity and the centre of flotation in a vertical line in the way indicated.

This plan was not used: the form of mounting determined on as regards that part above the polar axis required that the centre of gravity of this part should be some distance from the upper bearing; the following arrangement was then planned to meet this requirement, but it also was not used, as it involves

greater bulk than that finally adopted, and is only applicable to a permanent position.

In this the liquid proposed to be used is water or oil, the polar axis being made very much larger to get the necessary displacement, not only to carry itself and the weight of the telescope, but also to carry such a weight at the lower part as would bring the centre of gravity of the whole in such a position to the centre of flotation of the immersed part as to cause the axis to float at the required angle. For example, if we take the case of an 8 foot mirror, with a mounting for the upper part the same as my 3-foot telescope, we should have about nine tons, to be supported at a distance of about 8 feet from the upper bearing. If we now make a polar axis of boiler-plate about 50 feet long and 8 feet mean diameter, cylindrical, or preferably conical, and immerse this in water, we should be able by adding weight at the lower part to get such an arrangement that if the whole were placed in water it would float at the angle required, with the upper bearing above the water; it would then be only necessary to provide proper bearings for top and bottom, and add sufficient weight to ensure contact of the axis, and moor it, as it were, in its proper place, to complete an arrangement that would be, in my opinion, the best possible for the purpose. The weight we have taken as concentrated at the point 8 feet above the upper bearing can, of course, represent any form of optical arrangement that it is required to carry round, as, for instance, an Equatorial coudé; in this case the application would be easy, as the weights could be placed lower, and a continuation of the polar axis, of a similar but lighter construction, would form the tube and dispense with the upper bearing and pier otherwise needed. Or an arrangement for the use of a concave mirror, fixed at right angles to the polar axis at a distance something less than its focal length, with a plane mirror opposite to it similar in proportionate size, angle, position, and arrangement for turning, to the first mirror of the Equatorial coudé, the light of an object reflected from this plane mirror on to the concave mirror would be sent by this to a plane mirror placed, as in the Newtonian telescope, and fixed where the line joining the centres of the plane and concave mirrors, cuts the central line of the polar axis, from which it would pass out in the direction of this latter line, forming an image above, where it could be conveniently viewed or used.

The chief difficulty here would be the large plane mirror, but from what has been recently done, this may not be even a difficulty. If the plane mirrors can be made as easily and as well as the concave ones, such a plan of mounting allows them to be mounted in a very cheap and effective manner, and quite does away with the costly house or covering, and yet keeps all the advantages that other forms give.

May 1884.

Note on Dr. N. de Konkoly's Remarks on Mr. Hilger's Illumination of Micrometers with Vacuum Tubes. By Rev. S. J. Perry, F.R.S.

The adverse criticism of Dr. Konkoly appears to arise from a mistake. The micrometer exhibited at the meeting of this Society differs entirely in the method of illumination from the instrument at the Observatory of Kalocsa. The latter was constructed in 1880, and has a side illumination, whereas the curved vacuum tube in the Vizagapatam micrometer is placed inside the micrometer, and gives uniform illumination of the whole system of webs.

The whole of the Equatorial, including micrometer and circles, may be most conveniently illuminated by a couple of bichromate cells, with wires that may be attached as required to fixed vacuum tubes. Such a system of illumination has been in use for some time at one of the private observatories of Lancashire, and is found to answer perfectly. That Dr. de Konkoly can obtain equally satisfactory results with a number of small Swan lamps is a matter of congratulation.

Stonyhurst Observatory:
1884 *May* 7.

The Orbit of Pons' Comet. By J. Morrison, M.A., M.D., Assistant on the American *Ephemeris and Nautical Almanac*, Washington, D.C.

The only orbits of this comet which have been published are those of the late Prof. Encke and of Messrs. Schulhof and Bossert: the former deduced from observations extending over a period of only two months in the year 1812, and the latter from observations made in 1883, and subsequently corrected two or three times by equations of condition. Neither Encke's orbit nor that of Schulhof and Bossert represents the motion of the comet with that degree of accuracy which modern investigations demand. In order to obtain an independent determination of the elements, I select the three following observations made at Washington:—

Washington M.T.	Apparent α	Apparent δ
1883 Oct. 10·307425	248° 2′ 56″·1	+56° 51′ 49″·0
Dec. 27·249330	317 34 50·4	+29 31 14·8
1884 Jan. 21·299233	357 36 1·5	−13 31 23·1

The comparison stars were respectively, a *Berliner Jahrbuch*

star; *ζ Cygni*; and a 7th-magnitude star in *Cetus*, as given in the Catalogues of Weisse, Lamont, and Stone.

From these observations I obtain the following system of elements:—

T	... ...	1884 Jan. 25·729107, G.M.T.
ω	... ...	199° 12′ 50″·48 } Mean Equinox
Ω	... ...	254 9 45·82 } of 1884·0.
i	... ...	74 2 0·73
e	... ...	·95414506
log q	... ...	9·8896779
log a	... ...	1·2282918
P	69·572 years.	Motion Direct.

The residuals for the middle place are zero. It will be noticed that these elements differ considerably from those of Encke and Messrs. Schulhof and Bossert. The following residuals show how closely this system of elements satisfies the observations made from Sept. 5, 1883, to Feb. 5, 1884:

Date. Washington M.T.	C−O $\cos\beta\,d\lambda$	C−O $d\beta$	log Δ	Observation made at
1883 Sept. 5·11 +	− 3″·57	−3″·72	0·3668189	Milan.
23·32 +	− 3·65	−5·09	0·3282883	Washington.
Oct. 31·29 +	− 6·14	−6·59	0·2103271	„
Nov. 1·33 +	+ 3·73	−6·90	0·2060407	„
27·29 +	+ 4·82	+7·90	0·0707879	„
Dec. 6·25 +	+10·03	−1·18	0·0093336	„
21·24 +	+10·60	−7·20	9·8932833	„
1884 Jan. 3·23 +	− 3·12	−2·29	9·8126678	„
9·30 +	− 0·26	−1·48	9·8023359	„
17·30 +	− 0·82	−4·30	9·8246773	„
25·29 +	− 1·12	+1·10	9·8749017	„
Feb. 1·28 +	+ 1·78	+0·14	9·9258903	„
5·01 +	− 2·74	+1·23	9·9522952	Rome.

Owing to errors in the adopted position of the comparison stars, many of which have not been very accurately determined, and also to the uncertainty always existing in observations of comets in consequence of the ever varying form of the nucleus, these residuals are less than what we may reasonably expect to arise from these causes alone, not to mention the unavoidable errors of computation, even when seven-figure tables are employed, as in the present instance. The formation of equations

of condition for the purpose of correcting these elements, cannot be here applied with any advantage.

The only planets which can have any appreciable influence on the motion of the comet during the time it was in the neighbourhood of perihelion are *Venus* and the Earth. Assuming the elements I have obtained above as the osculating elements for the epoch Jan. 26·0, Greenwich Mean Time, the perturbations of the rectangular co-ordinates, arising from the action of *Venus*, are found to be as follows :—

Greenwich M.T.		δx	δy	δz
1884 Jan.	26·0	−0·0	− 0·0	+0·0
	31·0	−0·1	− 0·3	+0·1
Feb.	5·0	−0·2	− 1·0	+0·4
	10·0	−0·4	− 2·0	+0·9
	15·0	−0·6	− 3·2	+1·7
	20·0	−0·9	− 4·7	+2·6
	25·0	−1·3	− 6·5	+3·8
Mar.	1·0	−1·7	− 8·5	+5·0
	6·0	−2·1	−10·8	+6·5
	11·0	−2·6	−13·5	+8·0

which are expressed in units of the *seventh* decimal place. These perturbations do not sensibly affect the inclination, and their influence on the node is less than a second of arc ; they are then almost inappreciable, and, indeed, they scarcely exceed the uncertainty of the seventh decimal place in the final results of extended computations such as the one now under consideration. The perturbations of the rectangular co-ordinates arising from the action of the Earth are even less than those produced by *Venus*, by reason of the Earth being at a greater distance from the comet.

According to my elements, the aphelion distance is 33·056, which exceeds *Neptune's* mean distance from the Sun by about *three* mean radii of the Earth's orbit, and although the inclination is large (74° 2′), the comet will nevertheless be sensibly affected by the action of all the superior planets during the greater part of its period. The amount of this action during the last revolution may, perhaps, be approximately found by comparing my elements with those of Encke, as given in the *Annales de l'Observatoire de Bruxelles*, tom. I. If we refer Encke's elements to the mean equinox and ecliptic of 1884·0, and place them beside mine in order to facilitate comparison, we have the following results :—

	Morrison.	Encke.
T*	1884 Jan. 25·72917	1812, Sept. 15·313553
ω	199° 12′ 50″·48	199° 17′ 5″·89
☊	254 9 45·82	254 1 28·91
i	74 2 0·73	73 56 57·41
e	0·95414506	0·9545412
log q	9·8896779	9·8904995
P	69·572 years	70·684 years

Assuming these values of T to be correct, the actual period of the last revolution was 71·3605 years, and therefore Encke's period has been increased by 247·09 days. It is very probable, however, that Encke's elements are considerably in error, for Messrs. Schulhof and Bossert have deduced from the original observations of 1812 the following elements, which agree tolerably well with mine :—

$\pi - ☊ = \omega$	199° 12′ 32″·5	Mean Equinox, 1880·0
☊	254 6 15·3	
i	74 3 20·4	
e	0·9549960	
log q	9·8893650	

If we add 3′ 20″·92, or four years' precession, to ☊, we get 254° 9′ 36″·2, which is almost identical with my value, while the values of ω and i will not be sensibly affected by this change.

* Greenwich Mean Time.

Sextant Observations of Comet Pons-Brooks, as seen from the ship "Superb," Jan. and Feb. 1884. By Capt. D. W. Barker.

(*Communicated by Capt. H. Toynbee.*)

Date.	Lat. S.	Long. W.	Bar.	Alt. Ther.	Air Ther.	Corr. Chron. Time G.M.T.	✶ from which Dist. of Comet's Nucleus was measured.	Dist. of Nucleus from star.	Remarks.
1884.	° ′	° ′				d h m s		° ′ ″	
Jan. 15	26 27	127 40	30·173	82	77	15 17 1 32	Achernar	60 27 22	Bright, well defined nucleus, with short and faint tail pointing in a N. direction; about $2\frac{1}{2}^{\circ}$ long.
						3 52	α Tauri	78 58 47	
						5 25	β Ceti	24 21 2	
16	27 43	126 9	30·217	83	77	16 16 44 28	Achernar	58 4 17	Tail faint; nucleus round, bright in centre, and envelope visible all round.
						46 29	α Tauri	78 5 47	
						47 48	β Ceti	22 4 7	
28	48 48	97 33	29·800	59	49·4	28 15 53 27	Achernar	36 31 39	Intrinsic brightness of nucleus about the same as α Sculptoris
						15 58 10	Aldebaran	72 38 4	
						16 1 29	β Ceti	6 30 19	
						16 3 48	θ Eridani	36 11 44	
30	50 57	90 14	29·982	59	47	30 15 24 44	Achernar	33 49 14	
						27 9	Canopus	68 48 24	
						30 5	Rigel	68 44 9	
						Not visible again till Feb. 16 on account of cloudy weather.			
Feb. 16	37 45	36 58	30·045	64	58	16 11 0 39	Achernar	17 33 59	Much fainter, and tail not distinguishable at all to naked eye.
						3 33	θ Eridani	19 5 19	
						7 5	α Tauri	72 7 34	

After Feb. 16 it became too faint for sextant observation. The chronometer time is corrected for rate, and the distances for index error of sextant.

Sextant Observations of Comet Pons-Brooks, made on board the ship "Earnock." By Capt. George F. Parson.

(*Communicated by Capt. H. Toynbee.*)

1884.	A.T.S. P.M.	G.M.T. d h m s	Lat. S. ° ′	Long. W. ° ′	Aldebaran. ° ′	β Ceti. ° ′	Sirius. °	Achernar. ° ′	Fomalhaut. ° ′	Canopus. ° ′	α Arietis. ° ′	Rigel. ° ′	Markab. ° ′
Jan. 15	8 10	15 10 28 41	12 15	32 35	78 59	24 39*							
16	8 33	16 10 55 30	14 48	33 10	78 15		106 39		26 36				
17	7 48	17 10 10 0	17 0	33 2	77 29				25 27	92 38		84 4	22 55†
	8 20	17 10 43 0				20 19			25 17				23 1†
18	7 50	18 10 12 0	19 6	33 6		18 10			24 9			82 20	24 8‡
19	8 15	19 10 40 0	21 50	33 0		16 13			23 9			80 49	25 29§
20	8 0	20 10 20 0	24 14	31 50		14 20			22 20			79 29	26 42§
21	8 24	21 10 38 0	25 50	30 32		12 31			21 39			78 7‖	
23	8 35	23 10 35 0	25 48	27 0		9 22		44 52	20 42		49 16	75 32¶	
25	8 15	25 10 15 0	29 35	25 56		7 1		41 33	20 30		50 23	73 19**	
26	8 50	26 10 40 0	31 0	24 10		6 18		39 59††					
27	9 5	27 10 47 0	32 40	22 0		6 4		38 19				71 16	
30	10 0	30 10 53 0	38 40	10 28				34 5				69 5‡‡	

Feb. Owing to moonlight nights or cloudy weather no observations were obtained until Feb. 22, when the comet (invisible to the naked eye) was seen by the aid of an ordinary ship's telescope about 1° or 1½° N.E. by E. from an unnamed star, whose distances are as under. The comet lay somewhat to the right of a line from said star to Canopus, bearing and distance being of course only estimated.

					E.								
22	8 35	22 4 4 0	41 30	70 50				14 8				60 17	
Mar. 3	8 0		42 0	113 0			Comet distinguishable through telescope, but too faint for sextant observations.						

* Nucleus about 2nd magnitude, tail N.E. by E. 4°.

† Nucleus not visible until after stars of 3rd and 4th magnitudes have appeared, though after dark it appears about as bright as Markab, though less clearly defined.

‡ Tail very indistinct, though it lights up when a cloud obscures the larger stars in its vicinity.

§ Good observations. Tail more distinct. ‖ Tail visible halfway to η Ceti. ¶ Tail brighter than usual.

** Good observations. †† Tail visible halfway to β Ceti. ‡‡ Observations not very good.

Sextant Observations of Comet Pons-Brooks, January 1884. By Capt. A. S. Thomson.

(*Communicated by Capt. H. Toynbee.*)

Position. Lat. N.	Position. Long. W.	Date.	G.M.T.	Centre of Nucleus and Star	Angular distances.	Barom. at 32° F. and at sea level.	Temp. of Air, F.	Remarks.
° ″	° ′ ″		h m s		° ′ ″	in.	°	
28 28 0	16 0 45	Jan. 17	7 57 40	Algenib	23 0 54 mean of 3 obs.	30·32	65	The tail of the comet which shines faintly appears to the naked eye about 4° of arc in length, pointing towards the Pleiades. The nucleus is ill-defined, and its apparent diameter is about equal to that of the planet Jupiter. The angular distances observed between two stars are noted as an indication as to the value of the comet distances observed under similar conditions.
			8 17 40	α Pegasi	21 20 51 „ 3 „			
			8 44 23	Algenib & α Pegasi	16 31 1 single obs.			
			8 48 23	β Ceti	20 34 49 „			
			9 7 54	Algenib	23 2 50 mean of 2 obs.			
28 26 30	16 5 0	18	8 19 30	Algenib	24 10 17 „ 3 „	30·32	67	
			8 35 10	α Pegasi	23 35 17 „ 3 „			
			8 47 10	β Ceti	18 28 23 „ 3 „			
			8 58 40	Algenib & α Pegasi	16 29 59 „ 3 „			
28 34 40	15 43 20	19	8 32 15	Algenib	25 24 59 „ 2 „	30·41	65	The tail of the comet now points a little to the north of the Pleiades.
			8 57 20	α Pegasi	26 33 44 „ 3 „			
			9 6 0	β Ceti	16 25 44 „ 3 „			
			9 15 0	Algenib	25 25 10 single obs.			
			9 30 0	Algenib & α Pegasi	16 30 41 „			

Position. Lat. N.			Long. W.			Date.	G.M.T.			Centre of Nucleus and Star	Angular distances.				Barom. at 32° F. and at sea level.	Temp. of Air, F.	Remarks.
°	′	″	°	′	″		h	m	s		°	′	″		in.	°	
28	30	20	16	2	30	Jan. 20	8	24	18	Algenib	26	44	11	mean of 3 obs.	30·40	64	
							8	39	4	α Pegasi	28	33	50	,, 3 ,,			
							8	50	14	β Ceti	14	31	15	,, 3 ,,			
							9	2	56	Algenib & α Pegasi	16	30	41	single obs.			
28	28	0	16	14	0	21	8	53	54	Algenib	28	8	16	mean of 3 obs.	30·45	64	
							9	9	12	α Pegasi	30	34	46	,, 3 ,,			
							9	19	5	Algenib & α Pegasi	16	29	28	,, 3 ,,			
28	28	0	16	14	0	22	8	10	24	Algenib	29	31	33	,, 3 ,,	30·50	63	The tail of the comet is becoming gradually fainter; is about 4° of arc in length, and points towards a position midway between the Pleiades and Aldebaran.
							8	20	14	α Pegasi	32	27	16	,, 3 ,,			
							8	33	27	β Ceti	11	2	14	,, 3 ,,			
							8	52	24	Algenib & α Pegasi	16	30	31	,, 4 ,,			
28	28	0	16	0	0	23	8	58	3	Algenib	31	10	10	single obs.	30·47	62	
							9	4	3	β Ceti	9	28	26	,,			
							9	7	53	Algenib	30	58	46	,,			
28	28	0	16	5	0	24	8	39	52	β Ceti	8	12	12	,,	30·45	63	The tail of the comet now appears about 5° of arc in length, and points to Aldebaran.
							8	51	52	Algenib	32	23	47				

Position. Lat. N.	Position. Long. W.	Date.	G. M. T.	Centré of Nucleus and Star	Angular distances.	Barom. at 32° F. and at sea level.	Temp. of Air, F.	Remarks.
° ′ ″	° ′ ″		h m s		° ′ ″	in.	°	
28 24 0	16 9 0	Jan. 25	9 1 25	Algenib	33 48 36 single obs.	30·44	62	
			9 8 10	β Ceti	7 7 3 „			
28 26 0	16 6 0	26	8 12 54	Algenib	35 11 36 mean of 3 obs.	30·40	64	
			8 23 8	β Ceti	6 27 17 „ 3 „			
			8 32 54	Algenib	35 12 48 „ 3 „			
			8 40 21	β Ceti	6 26 32 „ 3 „			
28 26 40	16 5 50	28	8 8 34	Algenib	37 55 10 single obs.	30·38	66	The tail of the comet now appears very dimly, and points a little to the southward of Aldebaran.
			8 22 34	β Ceti	6 17 45 „			
			8 34 4	α Pegasi	42 43 16 „			
28 28 0	16 6 0	29	8 29 53	Algenib	39 14 28 „	30·33	66	
			8 37 48	β Ceti	6 47 45 „			
			8 42 8	Algenib	39 13 57 „			
30 31 0	15 56 15	30	8 27 28	α Pegasi	45 37 45 „	30·23	67	
			8 33 58	β Ceti	7 29 28 „			
28 29 0	16 10 0	31	8 36 37	β Ceti	8 24 59 „	30·29	67	The moonlight and low altitude of the comet now cause the nucleus to be too indistinct for further observation with the sextant.
			8 48 7	α Pegasi	47 1 43 „			

Elements of the Orbit of Comet a, 1884. By J. Tebbutt.

My observations of Pons' Comet having been interrupted on several occasions by cloudy weather, I have been enabled to devote some time to the calculation of the orbit of the comet whose positions I sent to you by a former mail. For the determination and verification of the elements I selected the following four Windsor positions, which are given with reference to the ecliptic and the mean equinox of 1884·0, but are uncorrected for aberration or parallax.

Greenwich M.T.	λ	β
d	° ′ ″	° ′ ″
Jan. 18·98218	327 23 13·7	−31 51 4·0
22·97140	331 9 25·7	−33 42 43·7
27·95377	334 58 39·6	−35 21 57·5
Feb. 1·98249	338 10 39·7	−36 36 2·9

As the comet was very faint at the time of the last observation, I adopted the first three places as a foundation for the calculation, and arrived at the following system of parabolic elements:—

T	... ...	= 1883, Dec. 25·30038, G.M.T.
π	... ...	= 125° 44′ 23″·9 } Mean Equinox,
Ω	... ...	= 264 23 59·6 } 1884·0.
i	... ...	= 65 0 54·8
log q	... ...	= 9·4910464
q	... ...	= 0·3097750

Motion Retrograde.

These elements reproduce the first three positions thus, the residuals being regarded in the sense of *calculation minus observation*:—

	$\Delta\lambda \cos\beta$	$\Delta\beta$
	″	″
Jan. 18	−0·7	+0·6
22	−3·9	+4·0
27	−0·2	0·0

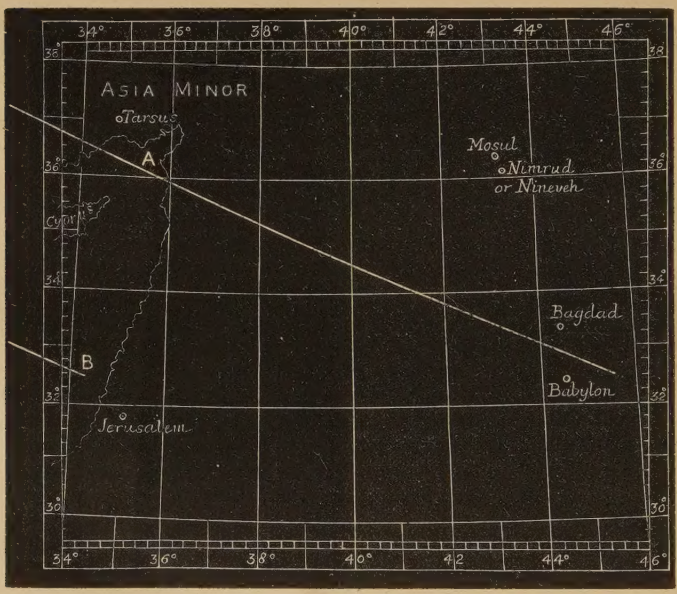
My last observation is represented thus:—$\Delta\lambda \cos\beta = -14''{\cdot}0$, $\Delta\beta = +14''{\cdot}4$, so that the above set of elements may be regarded as fairly representing the Windsor observations uncorrected for aberration and parallax. I trust when more extended observations are available to be able to take these corrections into account. No notice of this comet has appeared in the *Astronomische Nachrichten* to January 8, the latest date to hand, so it

is highly probable that the comet has escaped observation in the northern hemisphere. I trust, therefore, that the observations and elements which I have communicated may be of interest to the Society.

Observatory, Windsor, N.S.Wales:
1884 *March* 4.

Note on the Eclipse of Thales. By J. Maguire.

The solar eclipse of Thales, B.C. May 28, 585, has been calculated by eminent astronomers from Hansen's Lunar Tables, altered and unaltered. At the time of their publication, more than a quarter of a century ago, they were used by Sir G. B. Airy, then Astronomer Royal, for the calculation of this eclipse in Asia



Minor, as shown on his map in vol. xxvi. of the *Memoirs*. In this volume the latitudes and longitudes are given for points on the central and limiting lines of the shadow, but not the times at which the phase occurs. I adopted the Right Ascensions and Declinations of the Sun and Moon at the hours of two and four, as given under the letter K in the elements; and though I had no doubt of their accuracy, I nevertheless extracted all the par-

ticulars from the tables, and found a difference of only 3″ in the Moon's Right Ascension. For $3^h\ 37^m$ the data will be

		R.A.		Dec.	
☾	...	58° 12′ 43″·3		20° 54′ 46″·9	(D)
			a corr.	0 7·7	
☉	...	57 19 44·6		20 20 43·6	
a	...	0 52 58·7	*x* ...	0 34 11	

$$P-n = 3{\cdot}5643583$$
$$p\ 36^\circ\ \ 9{\cdot}9995010$$
$$P' \qquad 3{\cdot}5638593$$

The equation of time is taken $+9^m\ 8^s$, and the calculations made according to the method of Woolhouse, the resulting latitude being 35° 57′ 32″, and longitude 35° 50′ 45″: A representing this position on the accompanying map. Four more points on the central line have been calculated—the last being at $3^h\ 38^m\ 36^s$ in latitude 32° 28′ 50″, and longitude 45° 33′ 8″, the place of central ending—Bagdad and Babylon being within the limits of totality.

In 1872 it appears that Dr. Hind wrote a letter to the *Times*, which was copied into the *Astronomical Register* for September in that year, and giving an interesting account of several historical eclipses, among which is the famous one of Thales. He states at the outset that he employed the last value of the secular acceleration of the Moon's mean motion given by Hansen, and combined other important elements determined by him with the result of Leverrier's Tables of the Sun. He says his new calculation indicates that the eclipse was *total* in Nimrud for between three and four minutes shortly before sunset.

In 1879 Professor S. Newcomb, from his own Tables has placed the track of the *central* eclipse in the Mediterranean, the last position given being at B on the map, in latitude 32° 30′, and longitude 34° 12′.

As the celebrated and decisive battle between the Medes and Lydians is not supposed to have been fought near Jerusalem, nor to have been a naval engagement in the Mediterranean, the Professor's determination shows that if the battle-field is assumed to be in Asia Minor, the eclipse there must have been a *partial one*.

These are rather discordant results, the difference between the north and south determinations of centrality being about six degrees.

Norwich: 1884 *May* 13.